



Integrating Bioregenerative Foods into the Spaceflight Food system

Grace Douglas, Ph.D.

Advanced Food Technology Discipline Scientist

Human Research Program

NASA Johnson Space Center





Bioregenerative Foods



- Why do we want to introduce bioregenerative foods?
- What are the limitations to introducing them?
- How do we introduce them?





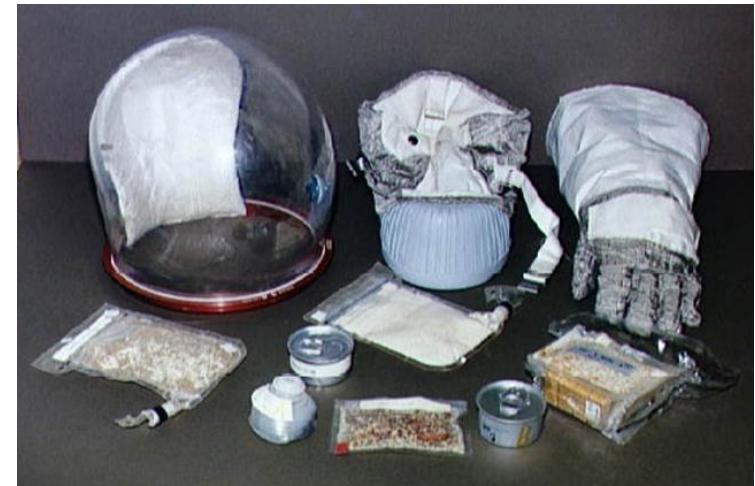
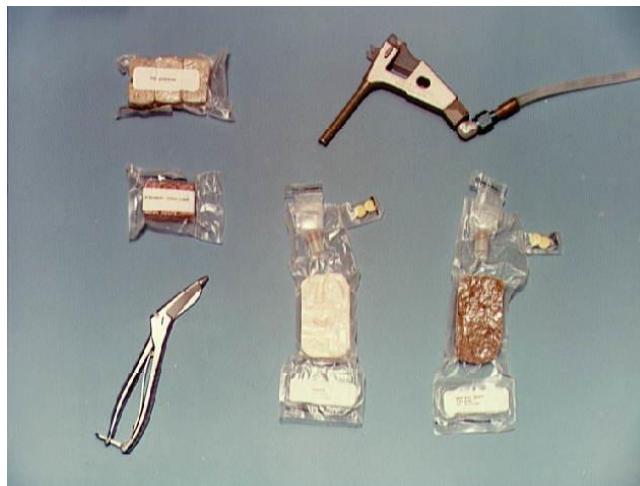
Space Food System Challenges



- Multi-year shelf stability
- No cold storage
- No cooking
- Limit crumbs and free liquid
- Minimal food transfer
- No washing or reuse of containers
- Minimal crew time for food preparation
- Resource Restricted – e.g. 2.5 L water per person per day



Food Systems: Mercury to Apollo





Food Systems: Skylab to early International Space Station



SKYLAB



SHUTTLE



INTERNATIONAL SPACE
STATION



International Space Station 2008-Current



200 options in 8 Standard Menu Categories

1. Breakfast
2. Rehydratable Meats
3. Meat and Fish
4. Side Dishes
5. Vegetables and Soups
6. Fruits and Nuts
7. Desserts and Snacks
8. Beverages



Bulk Overwrap Bag (BOB)

A set of 8 BOBS (one per menu category) will feed a crew of 3 for 7-9 days

Limited crew specific food, fresh food, condiments

No food refrigeration available on ISS

Shelf life of 1-3 years under room temperature storage



The case for prepackaged food

Goal: Exploration Food System that Promotes Crew Health And Performance

Food Safety Confirmed Prior to Launch



Less Infrastructure



Less Crew Time



No Risk of Food Scarcity



**Demonstrated ability to support
human health and performance for 6-
12 months**



ISS Compared to Mars



International Space Station:

- 6 month microgravity missions
- Radiation impact understood
- Regularly scheduled resupply
- No refrigerators or freezers for food storage, all food processed and prepackaged
- 7-9 day standard menu cycle augmented by crew preference foods



Mars Expedition Scenario:

- 2.5 year mission; micro- and reduced gravity
- Radiation impact is unknown
- No resupply; food may be prepositioned
- Availability of refrigerators or freezers for food storage is undecided
- Current food system is mass constraining and will not maintain nutrition/acceptability



The Constraints of Prepackaged Foods



Nutrient Degradation



**Quality Limitations and
Degradation**



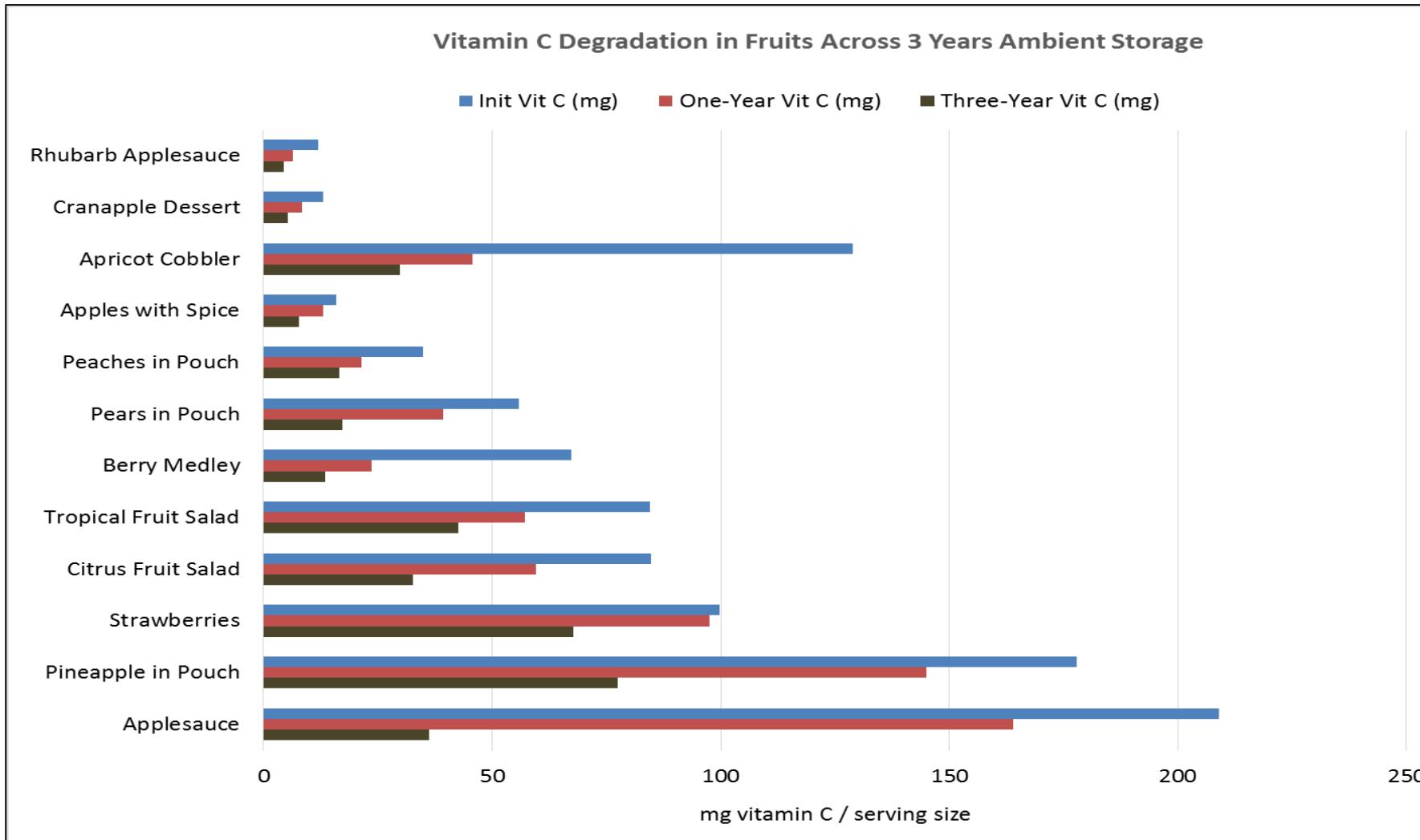
High Mass and Volume



No customization



Exploration Food System Challenge: Micronutrient Degradation





Functional Foods and Bioactive Compounds

Functional Foods provide
health benefits beyond basic nutrition
when consumed at effective levels as part of a
varied diet

(Hasler 2002)

Include compounds such as:

- Flavonoids
- Lycopene
- Lutein
- Sterols
- Omega-3 fatty acids

Potential health benefits:

- Improved nutritional status/bone health
- Reduced inflammation and oxidative damage
- Improved immunity
- Improved microbiota diversity
- Microbial production of beneficial metabolites

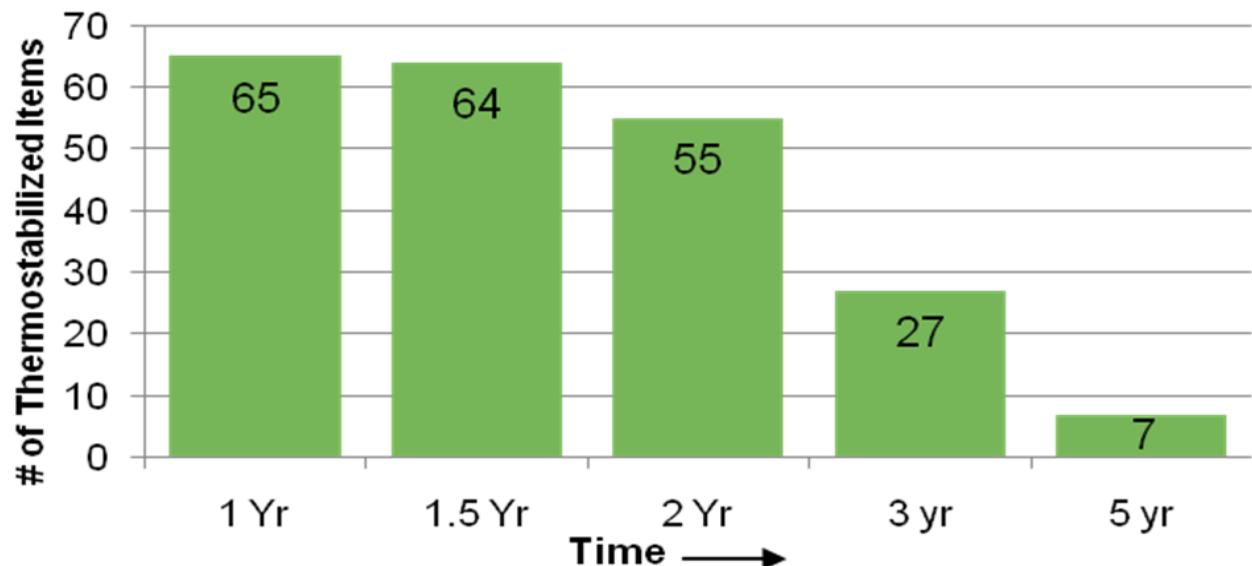




Exploration Food System Challenge: Acceptability and Variety



- Food quality relates to health and performance
- Food variety is limited in a closed system
- Food becomes more psychologically important with increasing mission duration



(Catauro. Journal of Food Science. 2011)



Prepackaged Food Strategies: 5 Year Shelf Life



Focus on nutritional stability, acceptability, health promotion

Formulation



Fortification
Ingredients and Matrix
Functional Foods
Variety

Processing



Microwave Assisted Thermal Sterilization (MATS)
Lyophilization Improvement
Reduced Moisture

Packaging



Improve barrier
Reduce Mass
Improve Method
Improve Processing Compatibility

Environment



21°C -80°C
Temperature
Atmosphere
Radiation
Microgravity
Partial Gravity



The Case for Bioregenerative Foods



Agri-Therapy

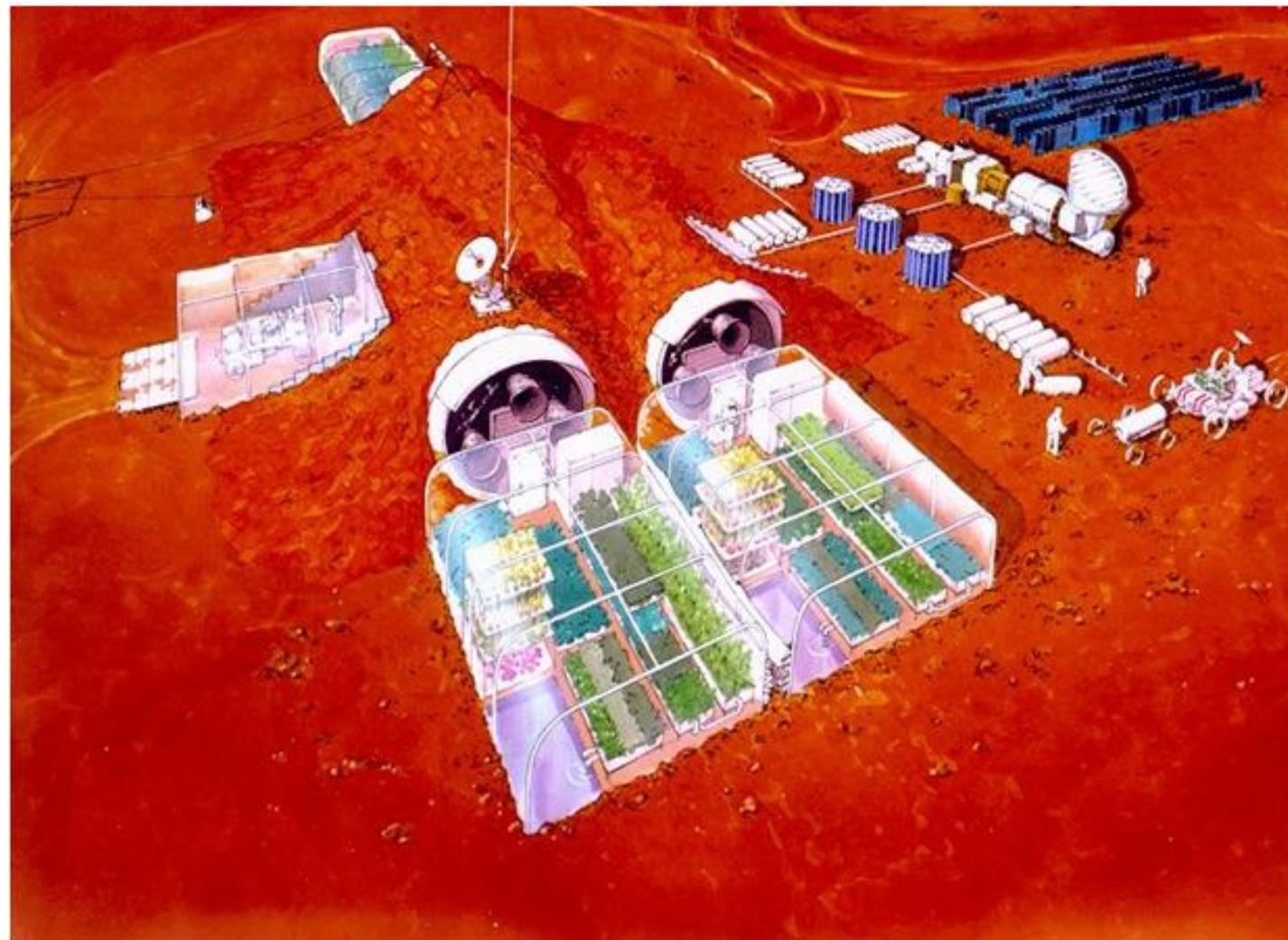
Psychological Appeal

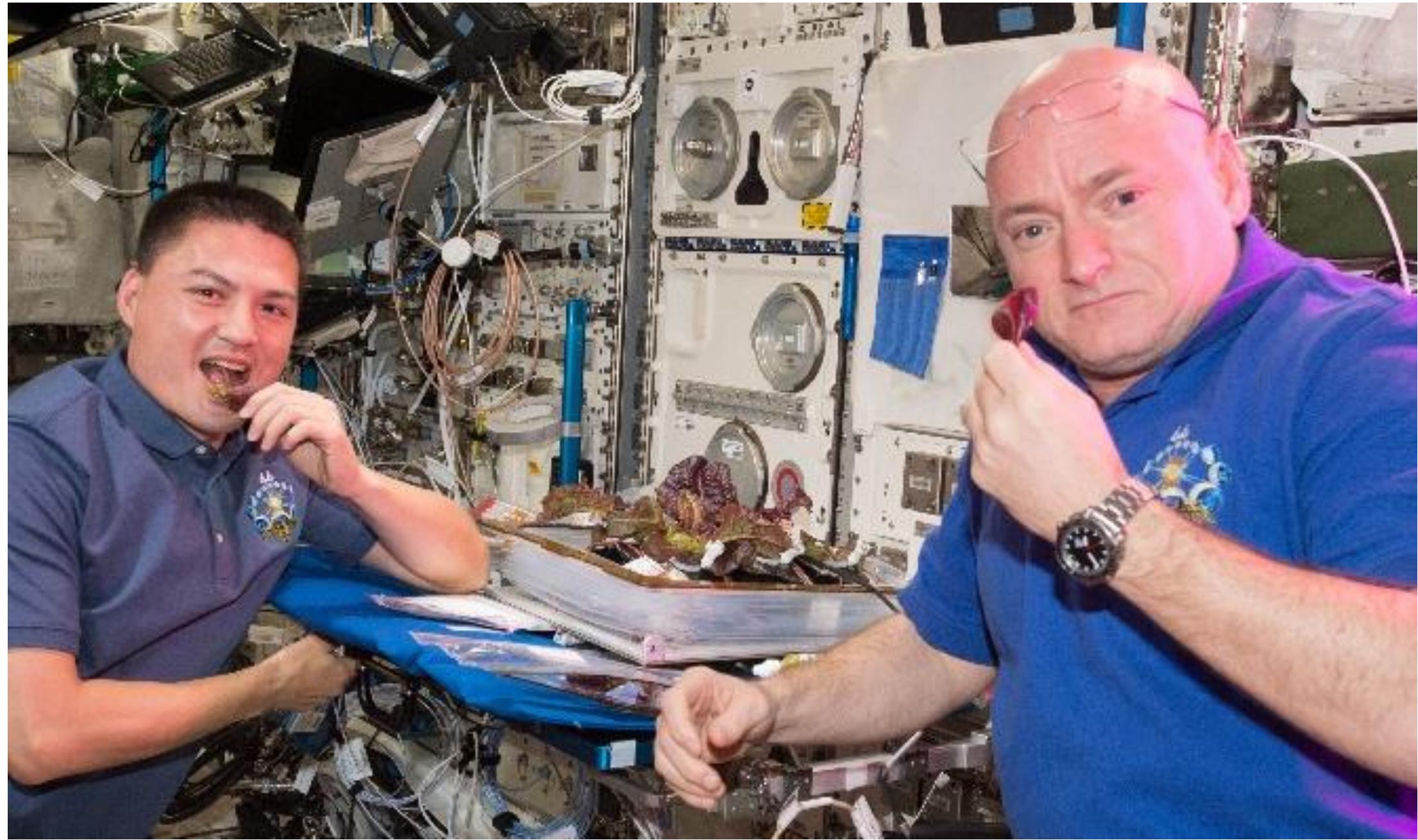
Higher Nutrient Density

Fresher Food / Quality

Variety / Customization

Goal: Earth Independence









The constraints of Bioregenerative Foods

Risk of Food Scarcity

Microbiological Risk

High Crew Time Requirement

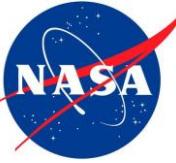
Infrastructure

Low Technology Readiness Level





Bioregenerative Food Strategies: Integrate Salad Crops



- First missions only pick and eat; supplement prepackaged food
- Validate technology and reliability of crop growth procedures
- Increase dependence on crops with technology maturation





Bioregenerative Key Food Points

- Establish Safety
- Establish Nutrition and Acceptability
 - Ensure Variety
- Mature all related technologies
- Promote Human Health and Performance

